

Probably many will think I might have relied more on our measurements, but I shall be content if they accept my conclusions; and I trust that the Royal Astronomical Society will be able to give, with my papers, such engravings of four of the photographs as will show the kind of agreement which exists.

Deal, August 24, 1872.

On the Arc of the Meridian Measured in South Africa.

By I. Todhunter, M.A. F.R.S.

1. It is well known that in 1752 La Caille measured an arc of the meridian in South Africa, and that the result obtained was decidedly larger than might have been expected from the measurements in the Northern hemisphere. It is also well known that Sir Thomas Maclear, formerly Astronomer Royal at the Cape of Good Hope, has in recent times carried on another measurement in South Africa, far more extensive than La Caille's, and that the result of the new operation is in harmony with the average of the trustworthy Northern arcs. Various references to these recent operations will be found in the *Memoirs* and *Monthly Notices* of the Astronomical Society; but I think no account has been given in these publications of the two large volumes issued in 1866 containing the details of the astronomical and geodetical work. There can be but one opinion of the value of Sir Thomas Maclear's measurement, and of the zeal and energy with which it was conducted. The Royal Society has marked its approbation by conferring a medal on the eminent astronomer; see the *Proceedings of the Royal Society*, vol. xviii. p. 109. The Lalande medal of the Academy of Sciences at Paris has also been awarded to Sir Thomas Maclear for this work.

2. The title of the volumes to which I have alluded is *Verification and Extension of La Caille's Arc of Meridian at the Cape of Good Hope*, by Sir Thomas Maclear, Astronomer Royal at the Cape of Good Hope. These volumes were published in England, under the editorship of the Astronomer Royal.

3. In consulting these volumes for the purpose of a *History of the Theories of Attraction and the Figure of the Earth*, it has appeared to me that there are some points in which explanations and additions are required; and I hope it may not be impossible to have a supplement of a few pages, for the sake of giving completeness to the publication. There must be at present various persons who are qualified to throw light on the subject; and thus it may happen that information could now be supplied which in a few years will be quite unattainable.

4. As the volumes now stand there is a very great discrepancy between the title and the contents. Instead of having "a verification and extension of La Caille's arc," we have the account of a new arc; and there is no comparison whatever of La Caille's *length* with the new *length*, though there is a comparison of La Caille's

amplitude with the corresponding part of the new amplitude. Thus when we read on the title-page of vol. i. as part of the contents, *Comparison of the Ancient and Modern Measures*, we are naturally led to expect what we do not find. There are apparently indications in the book that such a comparison was to be made; see pages 232, 403, 452, and 456. (All the references I shall have to make will be to the *first* volume.) There are also apparently allusions to some discussion of the disturbances produced by the attraction of Table Mountain; see pages 3 and 83, but no such discussion is given. We also read in the advertisement by the editor that "the publication of the work has been delayed about two years in the belief that it was the intention of Sir Thomas Maclear to add another sheet." And although we are afterwards told that "no addition is to be made," and that "the work is complete in itself," yet I venture to hope that something more will be soon supplied.

5. The amplitude of La Caille's arc was verified, as I have stated. The modern result does not differ from La Caille's by so much as half a second. We read on page 111 " . . . It redounds to the credit of that justly distinguished astronomer, that with his means, and in his day, his result from sixteen stars is almost identical with that from 1133 observations on forty stars made with a powerful and celebrated instrument." This is certainly a very remarkable confirmation of La Caille's accuracy; it must, however, be remembered that there is some uncertainty as to the exact spot which formed La Caille's northern station; this remark must be borne in mind throughout, though we shall not repeat it. La Caille had always enjoyed a great reputation for accuracy; see, for instance, the *Base du Système Métrique*, vol. iii. pages 162 and 544; and the article on the "Figure of the Earth" in the *Encyclopedia Metropolitana*, page 207. The confirmation of La Caille's value of his amplitude naturally increases the desire to compare his length with those of the recent survey.

6. According to page 219 of the article on the "Figure of the Earth" just cited, La Caille's arc is 1051 feet longer than corresponds to the average of the arcs in the Northern hemisphere. Taking the amplitude at $1^{\circ} 13' 17''$, this is at the rate of about 860 feet for a degree.

7. A letter written at the Cape of Good Hope by Sir Thomas Maclear, dated the 6th of May, 1846, and addressed to Schumacher, is published in the *Astronomische Nachrichten*, Number 574, September 3rd, 1846; the number forms part of vol. xxv. Here we find some of the comparisons which we require. The lengths of the five principal lines in La Caille's triangles are given, according to La Caille's own numbers, and also as deduced from the modern base with La Caille's triangles. According to this it seems that La Caille's numbers are about $\frac{1}{30000}$ th part too large. It is stated that these differences would disappear by subtracting about fourteen feet from La Caille's base. La Caille's

base, however, seems to have been measured with great care; see pages 432, 436 of his memoir in the Paris *Mémoires* for 1751. The lengths of three of the lines are also given as calculated from the modern base with the modern triangles; these scarcely differ from those calculated from the modern base with La Caille's triangles: hence I presume we may infer that La Caille's geodetical angles were sufficiently accurate.

8. The letter contains another very important table, from which I extract the following, which relates to the distance between Cape Town and Klyp Fontein,—

Amplitude. ° ' "	Length.	Length of 1°.
1 13 17.33	445506 feet	364728.8 feet
1 13 17.33	445361	364607.5
1 13 14.51	445027.51	364568.3

The first is said to be La Caille's result; the second, the result with La Caille's triangles and the modern base; and the third, the result with the modern geodetical and astronomical measurements. The lengths are given in English feet, except La Caille's arc; this is put at 69669.1 toises, which I have turned into feet. It ought to be observed that La Caille's toise has been held to have been somewhat too long, in consequence of which his degree was three toises too short; see Lalande's *Astronomie*, 3rd edition, Art. 2649. Then we read, "There is no necessity for examining at present why La Caille's measurement of the degree between Cape Town and Klyp Fontein should exceed the modern measure of the same by 160 feet. That inquiry may be worth consideration when the present work shall have been rigorously reduced." Thus it would appear that the modern measurement effected a reduction of only 160 feet in the length of the degree as derived from La Caille's original arc. But there is here a serious difficulty; for the modern amplitude is now taken as nearly *three* seconds less than La Caille's, whereas originally these amplitudes were made to agree within less than half a second; see Art. 5. I do not understand this contradiction.

9. The letter in the *Astronomische Nachrichten* contains some other interesting points which may be noticed. It is asserted decidedly that "no use can be made of La Caille's arc, properly so called, in the question of 'The Figure of the Earth.'" Again, "The chief cause of the failure of the measurement of 1752 rests with the circumstances of the terminal points." Then it is stated that Table Mountain to the south of La Caille's southern station, and high mountains to the north of the northern station, exerted an influence: "Consequently the arc is shortened by the sum of the deflections at its termini." It is stated that "Klyp Fontein station is close up in the south-west angle of large mountains;" but this is not quite clear, because we do not know the point of reference or origin from which we are to proceed to the south-west.

10. With respect to the disturbances and to the attraction of mountains it is uncertain whether the opinion of Sir Thomas Maclear remained permanent. In the letter, as we have seen, he attributes the anomaly entirely to this; but in the volumes I think he never decidedly takes the same view, though he certainly mentions mountains to the north of La Caille's northern station; see pages 39 and 403. But judging from La Caille's map and from Sir Thomas Maclear's Plate V., the preponderating action at the north end does not seem to be obviously and decidedly towards the north; the mountains extend not indeed directly *south* of the station, but still south of the latitude of the station, as well as north of the station. Again, as to Sir Thomas Maclear's *southern* station, we read in the letter, "Zwart Kop is about eight miles on the meridian north of Cape Point, and it is adopted as a southern terminus of the arc in preference to Cape Point, because Cape Point is the termination of a rugged peninsular range of mountains, without any solid matter above water to the south, and is therefore objectionable as the end of an arc of meridian, although interesting as affording the materials for a philosophical experiment." It is uncertain whether the opinion of Sir Thomas Maclear on this point remained permanent; but judging from the volume it would seem that Cape Point is really the better terminus; see page 609.

11. Now let us turn to the *Monthly Notices* of the Astronomical Society, vol. vii. 1847, page 58. Here we read, ' . . . Mr. Maclear (1840-41) carefully measured a base of 42,000 feet, nearly on the site of La Caille's, and then reobserved all his triangles, feeling confident that the former stations had been recovered in every instance to within a few feet. The length of the degree thus found halved the difference between La Caille and the modern state of the theory, being about 200 feet less than that of the former, and about as much more than that of the latter.' There are difficulties here. First, we have 200 feet assigned for the excess of La Caille's degree above that recently obtained, whereas it is elsewhere put at 160 feet; see Art 8. Secondly, we have the error that the whole difference between La Caille's degree and that of modern theory is about 400 feet; whereas we know it is about 860 feet; see Art. 6. There is another error on the same page of the *Monthly Notices*; it is asserted that the modern arc is of about $4\frac{1}{2}$ degrees, terminating at Khamies-Berg station; but the fact is, that the arc up to this station would be of about four degrees, and the additional half degree was obtained by proceeding beyond Khamies-Berg.

12. Next we take the *Monthly Notices*, vol. xviii. 1857, pages 313-16. Here we have a very important letter from Sir Thomas Maclear giving an account of his operations. We read, at page 315, that "the distance between Bradley's Sector-station at Klyp Fontein and the Rogge Berg Sector-station is, by the modern triangulation, 445018.14 feet." I assume that Rogge Berg is a misprint for Rogge Bay. Then to find the length of

La Caille's arc we must allow for the slight difference between his end points and those here named. According to the *Verification and Extension*, page 111, we have to add $206 + 45$ feet on this account, and so we obtain 445279.14 feet for the modern value of La Caille's arc. The difference between this and La Caille's own result is about 235 feet. It may perhaps be inferred that when all the geodetical work for La Caille's arc is rendered perfect, there remains still an excess of about 800 feet. This for want of any other explanation we may attribute to disturbance of his zeniths by local attraction; it corresponds to about eight seconds as the sum of the deviations produced at both ends. We may observe that Sir Thomas Maclear's own arc would have apparently suffered about eight seconds of error if he had not prolonged it through the last half degree; see his page 609.

13. There is a difficulty on page 314 of the volume of the *Monthly Notices* last quoted. The height of Heerenlogements Berg is stated in one place to be 2381 feet, and in another 1939 feet; perhaps in the second place we ought to substitute Zwart Kop.

14. Sir Thomas Maclear devoted great attention to the investigation of the precise points which La Caille took for his extreme stations; there are, however, some matters which do not appear quite clear. We begin with the situation of La Caille's observatory in Cape Town.

15. We read on page 9, " . . . carries us . . . to the point marked on the plan as the probable site of the Observatory." Perhaps by the word *point* here is meant the *shaded rectangle* in Plate I.; or perhaps *observatory* is used instead of *sector*. If the shaded rectangle be intended for the observatory, the position does not seem to correspond with La Caille's statement that it was "at the *bottom* or *further end* of the court;" see page 7.

16. We read on page 9, "The meridian of his observatory passes to the east of Mrs. De Witt's house, a couple of degrees to the left of the high projection into the yard. . . ." And in a note, "The meridian of his sector, I believe, passed over the high buildings." It is not obvious what is here meant by "a couple of degrees," as we are not told where the centre of the circle is placed on which the degrees are taken. Then we are not told how it is certainly known that such was the position of the meridian of La Caille's observatory. The *high projection* appears to be different from the *high building of two stories* which is mentioned in the next page. The "meridian of the sector," which occurs in the note is, we may presume, not identical with the "meridian of the observatory," which occurs in the text. Finally, the "high building" of the note is perhaps identical with the "high projection" of the text, and a smaller structure than the "high building of two stories;" in fact, from the size of the last, there would be nothing definite in saying that the meridian passed over it.

17. We read on pages 9 and 10, "From the north-west wall

of the kitchen within the yard projects the pin, or spike, alluded to by Captain Everest, flattened at the end, where it is slightly turned downwards. In the flat portion there is a hole, and underneath, on the wall, is drawn a rectangular quadrilateral, bisected perpendicularly. A pencil of light through the hole falls on the middle vertical line at apparent noon. Captain Everest speaks of "a brass plate perforated with a small hole, and fixed horizontally in a vertical wall. . . ." *Memoirs of the Astronomical Society*, vol. i. page 262. This seems to be the only relic of La Caille's residence at his Cape Town Observatory; but it is difficult to imagine that the same object can be described as "a pin, or spike," and also as a "brass plate." In a note on page 10, we read, "This pin is in the meridian of the observatory" It is not obvious how the meridian of the observatory was known independently, so as to justify this statement. We might perhaps have expected such words as these, "It is natural to assume that the meridian of the observatory must have passed through this pin." In Plate I., the line which is apparently intended for the meridian of the observatory does not pass through the position assigned for the pin.

18. On page 10, we are told of "a high building of two stories," and also of "low buildings," which had been erected since La Caille's time. Then it is added, "The upper story of the high buildings is let to sail-makers, and the lower buildings to fishermen. The latter occupy the site of the observatory." The editor has found this passage difficult; he conjectures that *low buildings* should be changed to *lower story*, and he says in a note, that "the high buildings occupy the site of the observatory." On page 62, we read, "The upper story forms the sleeping-room of Mr. Vansittart, a relative of Mrs. De Witt, and the lower is a receptacle for household stores." This statement may perhaps refer to a year later than the former; but we see that if we adopt the suggested correction of *low buildings* to *lower story* in the former, then we have the use of both upper and lower story changed in the interval. Some further notice of the locality is given on page 412.

19. We will now advert to La Caille's northern station. On page 50, there is a table with respect to the points near this station. Here the azimuths of La Caille's north and south peak do not differ by so much as on page 42. Perhaps this may be the matter to which the note on page 50 refers.

20. On page 41, we read, "I soon found that I must distinguish the several masses from each other by names to prevent confusion in the entries." Then followed the names, among which we read, "The mountains close to the sector, La Caille's Mount." We find elsewhere, as on page 44, the names "La Caille's Foot," and "La Caille's Head." On Plate IV. there are two views and a profile. *La Caille's Mount* is not mentioned, though *La Caille's Head* and *La Caille's Foot* are. It does not seem certain what is really meant by *La Caille's Mount*.

21. The second view on Plate IV. is said to be "from 200 yards beyond the north end of the base line." It is not clear whether the 200 yards are to be taken in the direction of the base line produced. The profile is said to be "from north-west to south . . . looking east." This we may presume means "turning from north-west to south through the east;" but it is not certain. Plates V. and VI. do not agree as to the position of the south peak of La Caille's Mount. In Plate V. this peak is close to the middle peak, but in Plate VI. the two are much separated.

22. It would be convenient to have a distinct account of the numerous peaks to which La Caille's name is given, in order to be certain of identifying them again if necessary. The *Head* has apparently three peaks, and the *Foot* two, according to Plate V.; but the views on Plate IV. do not seem to indicate these very distinctly.

23. On page 403 it is said, that "the northern extremity is close up in a corner formed by a north-westerly bend of Picquet-Berg." The words *close up in a corner* do not seem to correspond with Plate V.; unless by *in a corner* we understand *outside* a corner.

24. The position of La Caille's northern station may perhaps have been fully made out; but this is a point on which naturally those who have examined the locality are entitled to decide; but there appear some difficulties to those who compare the accounts. La Caille's map is probably not to be treated as extremely accurate; but it does not quite agree in its figure of the mountains with Sir Thomas Maclear's plates. La Caille, in his *Journal*, pages 181 and 182, says that a wide prospect could be seen from his station, even Table Mountain, for example; in fact, almost all that could be seen from the summit of Picquet-Berg. And yet he speaks of the habitation called Klyp Fontein being at the *foot* of a mountain, *adossée au Picquet-Berg*. It is quite obvious that these statements completely apply to the site as fixed by Sir Thomas Maclear.

25. Various notices respecting the South African operations will be found by the aid of the Indexes to the *Monthly Notices* and the *Memoirs of the Astronomical Society*; but I do not think that there are any matters of importance in them to which I have not alluded except what will be found in two papers which I will now mention. One of these papers is by Captain Clarke in the *Monthly Notices*, vol. xix. pages 36-38; here the effect of the new arc in modifying the best results previously obtained is investigated. The other paper is a memoir in the *Memoirs of the Astronomical Society*, vol. xx. 1851, entitled "Report of Proceedings at the Royal Observatory, Cape of Good Hope." On pages 7-25, we have an account of the operations connected with the arc of the meridian from the autumn of 1842 to 1848; this resembles pages 402-418 of the *Verification and Extension*, but is not identically the same; both accounts are very interesting and

C

should be read. Here we find on page 7 "La Caille's measure was vitiated, and rendered useless as an element in the determination of the figure of the Earth, because his terminal points are affected by the sum of the attraction of Table Mountain and the northern end of Picquet-Berg." As I have already stated in Art. 10, there seems no such decided opinion recorded in the *Verification and Extension*.

26. In conclusion, I may say that it is much to be wished the volumes had been furnished with an index, or at least with a copious table of contents. Moreover, there are various places in which the editor in notes points out difficulties in the text and sometimes suggests corrections; it would be useful to know if in these cases any explanations can be furnished, or whether Sir Thomas Maclear himself always adopted the suggestions.

St. John's College, Cambridge,
October 8, 1872.

On Lord Lindsay's Preparations for Observations of the Transit of Venus, 1874. By Lord Lindsay and Mr. David Gill.

An account of any preparations for the observation of the Transit of *Venus* in 1874, will doubtless be of some interest to the Fellows of the Society, and it is partly with this in view, but especially with the hope of securing more perfect co-operation with other expeditions, that this preliminary account of our preparations has been drawn up.

The station selected is the Island of the Mauritius. Its very favourable meteorological conditions offer every hope of fine weather during the transit, whilst its geographical position is very favourable for the observation of retarded ingress, and sufficiently favourable for the heliometric method, *i.e.*, for the displacement in line of centres. The station having been thus selected we have for method of observation choice of,

1st. Observation of internal contact for application of the methods of Halley and Delisle.

2nd. Observation of external contacts by viewing the approach of the planet to the limb through the chromosphere, the light of the sun being dispersed by a powerful spectroscope.* (These observations are of course equally applicable, with co-operation at a northern station, to Halley's or Delisle's methods.)

3rd. The Photographic method.

4th. The Heliometric method.

There is something to be said in favour of each of these methods, and as it was found that two observers with efficient assistance, and good organisation could accomplish the whole it was determined to provide for them all.

We shall deal with them in succession.

* For a description of the method I should use for this purpose I refer the Fellows to a note of Padre Secchi to Professor Silliman, and which is to be found in *Sill. Journal*, Third Series, Vol. I., No. 6 (June, 1871), page 463.